Concurrent Engineering for the Management of Research and Development

Rubén Del Rosario
Interagency Coordination Manager
NASA John H. Glenn Research Center
Cleveland, Ohio, U.S.
Ruben.DelRosario@nasa.gov

L. Ken Keys
Industrial and Manufacturing Engineering
Cleveland State University
Cleveland, Ohio, U.S.
l.k.keys@csuohio.edu
Senior Member IAMOT

Paul F. Petersen
Industrial and Manufacturing Engineering
Cleveland State University
Cleveland, Ohio, U.S.
p.petersen@csuohio.edu

Injazz J. Chen
Ops. Mgmt. & Business Statistics
Cleveland State University
Cleveland, Ohio, U.S.
i.chen@csuohio.edu

Abstract: The Management of Research and Development (R&D) is facing the challenges of reducing time from R&D to customer, reducing cost of R&D, having higher accountability for results (improved quality), and increasing focus on customers. Concurrent engineering (CE) has shown great success in the automotive and technology industries resulting in significant decreases in cycle time, reduction of total cost, and increases in quality and reliability. This philosophy of concurrency can have similar implications or benefits for the management of R&D organizations. Since most studies on the application of CE have been performed in manufacturing environments, research into the benefits of CE into other environments is needed. This paper presents research conducted at the NASA Glenn Research Center (GRC) investigating the application of CE in the management of an R&D organization. In particular the paper emphasizes possible barriers and enhancers that this environment presents to the successful implementation of CE. Preliminary results and recommendations are based on a series of interviews and subsequent surveys, from which data has been gathered and analyzed as part of the GRC's Continuous Improvement Process.

Keywords: Systems Engineering, Project Management, Concurrent Engineering, Management of R&D, Management of Technology.

Introduction

Over the past thirty plus years the importance and need to manage projects across enterprise functions, such as new product development, created the need for project management (Kerzner, 2003). The increased focus on more new products on a continuous basis, faster, and better, evolved from weak project management (coordinator) to strong project management (cross-cultural, mini-business manager) (Keys, 1990a). Still increased pressure on faster to market, with increasing complex products, in overlapping release times, evolved to simultaneous processes and then concurrent engineering (CE) (Keys, 1991).

In the mean time the management of Research and Development throughout the world is being faced with the similar challenges of (1) Improvement in R&D to customer cycle, (2) Cost reduction to align with reduced budgets, and (3) Higher accountability for results with increased focus on customer needs. (Balderston, 1984; Mitchell, 2000; Roberts, 1995; Roussel, 1991)

The philosophy of Concurrent Engineering (CE) has shown great success in private industry, specifically in the automotive and technology industries. It is defined by R. I. Winner (1988) as "... a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support ... intended to cause the developers, from the outset, to consider all elements of the lifecycle from conception through disposal, including quality, cost, schedule and user requirements." Traditionally, all the activities during the product life had been accomplished following a serial or sequential approach. Referred by many as over-the-fence engineering the sequential approach allows specifications and designs to be frozen by only engineering design decisions early in the process and thus creating situations where upstream decisions will constrain downstream options leading to sub-optimal performance results with increased costs and development time (Keys, 1995). According to Keys (1990b) the primary motivator for the emphasis on concurrency is that the product design, while constituting a relatively small portion of the total product development cost, influences up to 80% of the life-cycle cost.

This paradigm of concurrency could have significant implications for the management of R&D and in particular the development of complex aerospace technologies and systems that are developed by Federal laboratories and their partners. This new way of developing technologies will produce changes in the ways aerospace systems are researched, designed, tested, produced, operated, maintained, and disposed of (Del Rosario, et. al. 2003).

Research on the application of CE has been performed in high-production and/or manufacturing environments. Research into the applicability and benefits of CE into a low/no production, service, research and development, and/or government environment is limited. Although most experts agree that aspects of this philosophy should be applicable to any kind of R&D setting, there is limited research on the subject, as it applies to a government R&D environment.

This paper introduces a research initiative conducted at the NASA Glenn Research Center (GRC) investigating the application of CE in the management of R&D. Throughout the years GRC has been involved in the development of advanced aircraft technologies, space propulsion systems, communication satellites, the International Space Station and others. Because of the diverse nature of the R&D projects envelope, GRC provides an excellent model for this type of research.

The study concentrates in the applicability of CE in the planning and implementation of experimental testing projects at this R&D facility in support of research projects. In particular the research identifies possible barriers and enhancers that this environment presents to the successful implementation of CE. Results and recommendations are based on a survey questionnaire completed by 119 GRC employees from the different functional areas currently involved in the performance of experimental testing activities.

Concurrent Engineering

As proposed earlier the benefits claimed by the use of CE seems to provide an answer to the challenges that R&D organizations are facing today. Although many experts have proposed that these benefits are transferable to any industry, research in the area of R&D is very limited.

To better understand the possible impact of CE we present a brief synopsis of the history of this philosophy. Traditionally all the activities of development have been accomplished following a sequential approach. In this approach, referred by many as over-the-fence engineering and officially documented by NASA in the 1960's, experts in each step perform their duties and pass the product to the expert of the following step. This allows specifications and design to be frozen by only engineering design decisions early in the process thus creating situations where upstream decisions will constrain downstream options (Keys, 1995). As defined earlier CE has been an attempt to enhance the development process by creating a systematic interaction of all the functions and expert areas. Concurrency does not eliminate any of the stages required for product development but instead it focuses on a holistic consideration of all of these stages.

Systematic studies within the automobile and technology industries have substantiated that for a successful implementation of CE various critical factors or characteristics must be present (Keys, 1992; Handfield, 1994; Durand, 1995; Youseff, 1994; O'Neal, 1993; Sobek, 1999; Duffy, 2000). These critical factors are:

1. Strong Management Commitment
2. Interdisciplinary and multi-talented teams
3. Comprehensive training to all team members
4. Adequate resources and tools
5. Early and continuous involvement of Customers and Suppliers

Also substantiated by many researchers is the fact that successfully implemented CE programs will provide three main benefits. These benefits have been summarized as: reductions in total product cost, reductions in cycle time, and improvement in quality and reliability.

Our study looks into the applicability of CE implementation in an R&D environment.

Research Methodology

The study was conducted in two phases. The first phase was exploratory in nature and accomplished by conducting a series of semi-structured personal interviews. A total of six GRC Division level management personnel, with a cross-functional view of the operation of research experiments, were interviewed. Although ordinarily unstructured interviews do not utilize interview protocols (schedule), protocols were used to provide overall guideline or framework for the conversation. The main objectives of these interviews were to provide data that helped in refining the research questions and guiding hypotheses, and to provide information that was used to develop the structured questionnaires to be utilized during the second phase. Content analysis (Gillham, 2000a; Kerlinger, 1973; Cooper and Emory, 1995) was used to analyze the information gathered during this phase and preliminary results have been previously reported (Del Rosario et. al., 2003).

The second phase consisted of the administration of structured questionnaires (surveys) to team members of various R&D projects within NASA GRC. A questionnaire was completed by 119 GRC employees from the various functional groups involved in the performance of experimental testing. The respondents were asked to rate, based on their experience and using a Likert scale from 1 to 7, statements relating organizational characteristics to elements of project success (a total of 33 statements). The data of this structured questionnaire was analyzed using appropriate analytical tools for content validity, reliability and statistical differentiation (Gillham, 2000b; Cooper and Emory, 1995; Rea and Parker, 1997; Cronbach, 1951; Stapleton, 1997).

Enhancers and Barriers for Concurrent Engineering in R&D

As mentioned before this paper introduces possible enhancers and barriers that a R&D environment presents to the successful implementation of CE. The results presented are part of a systematic research that assessed and evaluated the status of the use of the managerial tools and techniques of concurrent engineering on the success of experimental testing projects of a research and development organization. Although not presented in this paper the study also identified the potential benefits of CE in R&D. The results from this study were used to make recommendations and to propose a plan and strategy for strengthening the systems engineering and project management processes at NASA Glenn Research Center.

The research presented here explored how organizational characteristics of an R&D environment influence, positively or negatively, the elements of project success. Unique factors that enhance and/or impede the implementation of CE in the research and development environment were identified and analyzed. The research questions for this area of interest attempted to identify those characteristics that influence the project success. Three features of the project completion were analyzed. The features are: project cycle time, project cost, and quality and reliability of the deliverable. For the research the following research questions were assessed:

Q1. What are characteristics that positively influence projects to be completed on or ahead of schedule?
Q2. What are characteristics that positively influence projects to be completed on or below budget?
Q3. What are characteristics that positively influence projects to result in very high quality and reliable products or deliverables?

Q4. What are characteristics that negatively influence the projects schedule?
Q5. What are characteristics that negatively influence projects cost and budget?
Q6. What are characteristics that negatively influence product's quality and reliability?

To assess these research questions the respondents were asked to rate statements related to organizational characteristics using a 7-point Likert Scale. The respondent rated, with 1 rated as "Very Negative Influence" and 7 rated as "Very Positive Influence", the influence that the following statements have in project cost and budget, project schedule, and products/deliverables quality and reliability:

1. Current organizational structure
2. Collaboration amongst internal organizations
3. Current reward and recognition system
4. Procurement practices and regulations
5. NASA budget cycle
6. Effective use of system engineering and project management practices
7. Composition of project teams
8. Partnership with external suppliers of parts or services
9. Organization's effectiveness in prioritizing projects and activities
10. Unique technological nature of our projects
11. Rapid changes in technology

Research Findings

This section discusses the findings from the data obtained through the survey questionnaires and how the data relates to each of the research questions of the study. As stated before enhancers and barriers were qualitatively analyzed by measuring the level of positive or negative influence the respondents thought that current characteristics of a government R&D environment have in Concurrent Engineering.

Positive and Negative Influence in Cost

This area addresses the research questions of those characteristics that positively influence and those characteristics that negatively influence projects to be completed on or below budget.

Based on the responses there are four current characteristics that showed positive influence in projects to be completed on or below budget. The characteristics are: (1) Collaboration amongst internal organizations, (2) Effective use of systems engineering and project management practices, (3) Composition of the project teams, and (4) Partnership with external suppliers of parts or services. These characteristics could be related to a strong team environment within the GRC culture.

There were five characteristics that showed negative influence in projects to be completed on or below budget. These characteristics are: (1) Current reward and recognition system, (2) Procurement practices and regulations, (3) NASA budget cycle, (4) Organization's effectiveness in prioritizing projects and activities, and (5) Unique technological nature of our projects. Out of these, most could be related with management practices.

Positive and Negative Influence in Schedule

This area addresses the research questions of those characteristics that positively influence and those characteristics that negatively influence projects to be completed on or ahead of schedule.

Based on the responses there are four current characteristics that showed positive influence in projects to be completed on or schedule. The characteristics are: (1) Collaboration amongst internal organizations, (2) Effective use of systems engineering and project management practices, (3) Composition of the project teams, and (4) Partnership with external suppliers of parts or services. These characteristics could be related to a strong team environment within the GRC culture.

There were five characteristics that showed negative influence in projects to be completed on or below budget. These characteristics are: (1) Current organizational structure, (2) Current reward and recognition system, (3) Procurement practices and regulations, (4) NASA budget cycle, and (5) Unique technological nature of our projects. Also in this case most of these could be related with management practices.

Positive and Negative Influence Quality and Reliability

This area addresses the research questions of those characteristics that positively influence and those characteristics that negatively influence the quality and reliability of the products and/or deliverables.

Based on the responses there are seven current characteristics that showed positive influence in the quality and reliability of the products and/or deliverable. The characteristics are: (1) Current organizational structure, (2) Collaboration amongst internal organizations, (3) Effective use of systems engineering and project management practices, (4) Composition of the project teams, (5) Partnership with external suppliers of parts or services, (6) Unique technological nature of our projects, and (7) Rapid changes in technology.

There were two characteristics that showed negative influence in the quality and reliability of the products and/or deliverables. These characteristics are: (1) Procurement practices and regulations, and (2) NASA budget cycle.

Final Observations

Table 1 summarizes the perceived influence that each characteristic of the organization has in Cycle Time (schedule), Cost (budget), and Quality and Reliability. The letter "N" in this table refers to neutrality in the sense that no statistical difference was obtained between the mean of the responses and the central value of the scale. A positive sign (+) refers to perceived positive influence and a negative sign (--) refers to a perceived negative influence.

Table 1: Summary of Findings

Current Characteristics	Cycle Time	Cost	Quality
Collaboration Across Organizations	+	+	+
Effective use of SE and PM	+	+	+
Composition of Teams	+	+	+
Partnership with Suppliers	+	+	+
Rapid Technology Changes	N	N	+
Organizational Structure	--	N	+
Technological Nature of Projects	--	--	+
Effective Prioritization	N	--	N
Reward/Recognition System	--	--	N
Procurement Regulations	--	--	--
NASA Budget Cycle	--	--	--

As a general observation it was observed that some characteristics are present as positive or negative for all three elements of project success. The organizational characteristics of current collaboration amongst organization, the effective use of systems engineering and project management practices, composition of project teams, and partnerships with external suppliers seems to be positive influence across all elements of project success. These findings are consistent with other findings of the research which seems to suggest that a strong Systems Engineering and Project Management culture exists within this NASA organization.

On the other hand, the regulatory characteristics of procurement practices and regulations, and the NASA budget cycle seem to present a negative influence for all elements of project success. These characteristics seem to be impediments that must be addressed in order to minimize their impact on project success.

Of interest is that although the characteristic of current organization structure seems to positively influence the quality of the products and deliverable, it also seems to negatively influence the schedule of the project. Another characteristic with mixed effects is the unique technological nature of NASA GRC's projects. Although this characteristic is seen as having positive influence in the quality of the deliverables, it is also seen as having negative influence on cost and schedule. These mixed impacts suggest that caution must be exercised when addressing either of these organizational characteristics.

As conclusion it should be noted that in order to effectively implement a Concurrent Engineering program special emphasis is needed in addressing these characteristics perceived as having a negative impact on project success. The reality is that some of the negatively perceived characteristics are difficult to influence. However systematic training on how to work concurrency within the boundaries of these characteristics, such as the NASA Budget Cycle, could have positive outcomes. A recommendation of systematic training tailored to the findings of the studies is being developed for implementation.

Acknowledgements: The authors want to acknowledge all the NASA GRC employees that have taken the time to share their experiences either through the personal interviews or by completing the lengthy questionnaire. We would also like to express our appreciation to the GRC management who has opened their doors for this study.

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